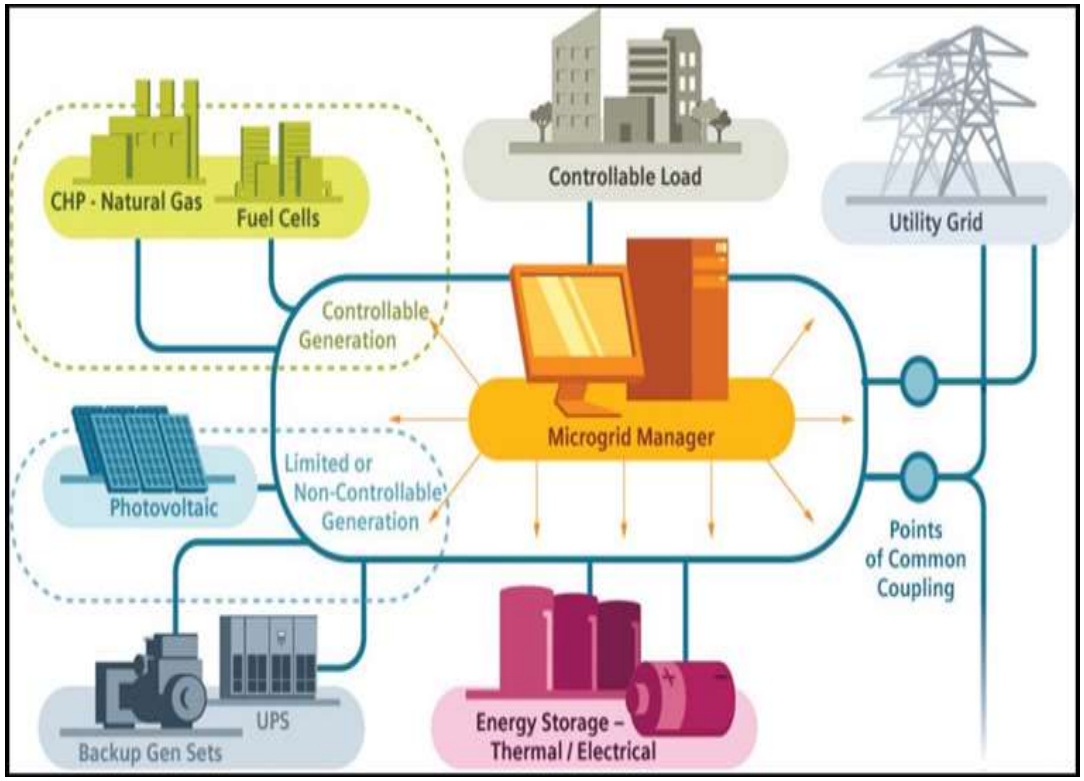
Akshay Prakas (issue No.3 of 2021)

"Special issue on Microgrids: Future of Energy "



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Also kindly excuse me for my typo errors ,if any

Complied By

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ME(Elect)

Date: 27/11/2021

What is a Microgrid (MG)?

- Microgrid is a small-scale distributed electricity Gen & Storage facilities & Dist system. (e.g. RT solar, wind turbines, Batteries, located near the loads).
  - MGs can vary significantly in size: from only a few buildings to large communities, but are all relatively smaller than Main Grid.
- In some instances, MGs can remain connected to Main Grid & there is a transition between grid-connected mode or autonomous 'island-mode'.

MGs generally encompass:

- Multiple types of Gen & Storage resources,
- Advanced Communication & Control Systems,
- Protection Systems & Operating mechanism, which allow optimisation tools to facilitate Energy Management & Demand Response (DR), balancing energy between MG's component parts.

- MGs: to provide reliable, resilient & economic power whilst reducing ENV footprint.

Characteristics of MICROGRIDS

- Produce optimised onsite Gen/Energy
- Size: From KW ranges up to more than 100 MW
  - Include Dist System to supply power to distributed loads
- Serves a distinct, interconnected load with single or multiple meters, within a defined geographical & electrical boundary
- Supports resiliency, security, efficiency, local control, & increased access to RES
- Can act as a single, controllable entity within the Central Grid
- Can operate in parallel to the grid, as a grid collaborator not a competitor
- Can be leveraged for economic value during grid- connected operations
- Can connect or disconnect from the main grid during interruption events with black-start capability (the ability to restart without reliance on external power).

- Elements of a MG could include: controllable Gen like natural gas-fueled combined heat & power (CHP) & fuel cells; limited or non-controllable Gen like a Solar PV array or wind turbine; backup Gens; uninterruptible power supply (UPS); & energy storage capability.
  - MG manager balances the Gen & load. MG interacts with the local Dist network thro' the points of common coupling.
- MG Can coordinate with other MGs, & with the entire power system
- Often incorporate advanced controls, communications & automation S/W for intelligent energy management & demand response, thro' the Artificial Intelligence (AI)
  - AI computing capability is key to shifting from Centralized monitoring & Control to Distributed Intelligence, where the MG can compute & take actions, independent of the centralised control
- May use any form of fuel, but are likely to include Diesel, (natural/propane) Gas, solar PV and/or wind power
  - May include storage technologies (battery, THM, H2 & pumped HEP)
  - MG may participate in Demand Response, & buy power from grid or sell energy, capacity & ancillary services to the grid, depending on economics/ pricing & system conditions

FIVE TYPES OF MGs

1. Connected Microgrids:

- These MGs normally remain connected to & collaborate with the Main Grid with the ability to trade power, storage & services between itself & other grids.
  - When a problem arises with the Main Grid, a connected MG can be protected by 'islanding', (i.e. disconnecting from the Main grid but continuing to serve power critical activities/Customers)

2. Autonomous/ Isolated MGs:

- These MGs are systems that are part of the electrical network & within the network service area but are disconnected from the Main Grid network (not synchronised with the Main Grid) & operate autonomously. They rely on Local Gen to support critical activities.

3. Remote Microgrids:

- These are in remote locations where Main Grid has not reached or Main Grid connection is not viable, for example a remote mine site or island community (Elephanta caves near Mumbai) They are not within the Network service area & have to rely on local Gen. Remote Microgrid is not a part of Main Grid network

4. Embedded MGs:

- Embedded networks are usually privately-owned grids, located behind a single connection point (malls, Hospitals). An embedded network may suit a commercial complex such as a University, Mall, Hospital or Retail centres.

5. Stand-Alone Power System (SAPS) Microgrids :

- Stand-Alone PS MG are not connected to any other networks & typically serves a single customer using hybrid power sources (mines)

All Five Types of MGs require local Generation & /or Local Stotage

What is not a Microgrid?

- A solar PV array without battery storage with advanced inverters, is not a Microgrid, because it cannot operate autonomously, matching Power Gen to Real-time demand.
- Similarly, a Diesel generator for backup power only, which doesn't synchronize with Main grid & supports only the emergency loads is also not a microgrid

Benefits of Microgrids

- MGs offer opportunity to deploy zero-emission electricity sources, thereby reducing greenhouse gas (GHG) emissions
- MGs can make use of on-site energy that would otherwise be lost & heat that would otherwise be lost up in the form of T&D losses & also the reduction in smoke-stack .
- MGs improve Local Power Supply Management, which can help to defer costly investments by utilities in new Power Gen & Trans
- Microgrids can enhance "Grid Resilience" to more extreme weather or cyber attacks.
  - MGs can continuously supply power to individual buildings, neighbourhoods, or entire cities, even if the Main Grid suffers an outage. (Islanding)
  - MGs can also help Main grid to recover from a system outage, either indirectly, by sustaining services needed by restoration crews, or directly, by helping to re-energize the feeders, during restoration

Drivers of Microgrids

Energy Access, Security & Autonomy:

Safe, reliable & affordable power is a prime-mover for economic growth

- **Rise of REs, Cost of Infrastructure O&M and Grid instability are constant challenges for PS operators**
- **In an islanded power system, MGs help Discoms in improving reliability & are more cost effective to maintain.**
  - **MGs are useful tools in creating efficient energy access in geographically remote areas, as well as developed Networks.**
- **Existing electrical infrastructure of centralised energy Gen/Trans & Dist is also at increased risk from more severe & frequent climate events due to Global Warming. MGs can mitigate those risks, improving energy security in a changing climate.**

Technology & Network Augmentation:

- **O&M cost of Old & depleted network infrastructures is High. MGs offer a cost-effective infrastructure Renewal option.**

- With variations of MGs popping up in the US & Australia, MG technology is also complemented by the knowledge & skills to implement, which are working towards increasing uptake of MGs by providing Smart Technology solutions (using Arificial intellegence) that offer higher Reliability, Reduced cost & Commercial opportunities for end user to replace ageing systems

RE Sources (RES) & Distributed Energy Resources (DERs):

- Grid connected large RES or Residential Rooftops is a key driver for MGs. MGs have capability to take on locally generated RE, & provide stability to the wider network. MG suits the needs of network operators looking to smooth RE flows.
  - MGs also suit needs of Power Gens: big or small: wanting to capitalise for their own use or Commercial opportunities or selling it back to grid.
- With existing fossil-fuel investments increasingly being written down & funding new ones more difficult, the uptake of REs on MGs will help to ensure longer term energy security.
  - Success of MG requires, a greater reliance on RES & a Battery storage System which can effectively manage & distribute RE.

Enablers for MGs:

- Increased need for Reliability & resiliency of energy supply.
- Proactive Regulatory policies for New Tariff structures
- Reducing cost of RE
- ESS/MG / DER management technology being mature.
- Increased Customer knowledge & understanding of MGs
- Customer/ investor perceived actual financial benefit of adapting MGs

Barriers for MGs:

- Initial CAPEX to install MGs. Perceived financial risk of adapting MG. Unfavourable project economics. Investor reluctance due to perceived risks
- Need for Standards or protocols
- Cost of MG management technology (Control of MG)
- Not enough scalable trials (pilots) have occurred nor compensation given to performing trials
- Pre-existing technologies installed, do not support MGs
- Shortage of skilled workforce to implement MGs on large Scale

What Is Artificial Intelligence?

- Artificial Intelligence (AI): Ability of a "machine", via computing iterations & algorithms, to perform cognitive functions ordinarily associated with the biological human mind.
  - Cognitive human actions such as reason, perception, deduction, problem solving & others, are performed using data & computing techniques
- Using a machine (a computer), AI can solve problems, learn patterns & iterations, & draw inferences that would otherwise be cumbersome for a human mind to accurately compute.
  - AI allows machines to process huge volumes of data & "learn" patterns from such data to accurately draw inferences that would otherwise be impossible for human minds to process.
- AI enables many different solutions for automation, robotics & efficient production in a range of INDs, including in design & operation of Microgrids & their supporting technologies.
  - MGs employ AI to take "Energy Management Decisions" with more autonomy, speed & precision

- **AI manages not only their internal energy resources of MG but also their relationship with the Main Grid.**
  - **Constantly seeking an optimal resource mix: based on energy prices, sustainability, reliability or whatever goals MG operator establishes. they at times rely on their internal Gens & ESS and at other times turn to the Main grid for energy.**
- **MGs also come to the aid of the grid when it is under stress, contributing energy & services and receiving revenue in return. Main grid may need these services, when it is in danger of demand exceeding supply, such as when wind & solar resources suddenly stop performing.**
- **So, planning & managing MGs can be complex because they operate within a landscape of variability & change.**

Microgrids:

- **Constantly seek for optimal mix of resources, which changes based on fuel availability, pricing, emissions and other factors.**
- **Navigate dynamic energy markets, which pose price opportunities & challenges.**
- **Balance sometimes unpredictable energy Demd & intermittent forms of RE supply, both within their own footprint & on the Main grid.**

AI can be applied in planning, deployment & operation phases of a MG, to benefit MG developers, equipment providers & integrators, and operators.

ARTIFICIAL INTELLIGENCE (AI): A Solution

AI excels at solving critical PS Management Challenges:

- By adding a layer of AI to existing Dist Management System (DMS), utilities can vastly enhance their ability to manage complexity & adapt to change.
  - AI enables utilities to become better prepared for extreme temps, severe weather events.
  - AI can also help utilities cope with sudden surges or drops in energy supply & Demd that are becoming more common as more intermittant Distributed Energy Resources (DERs) are connected to the Main grid.
- AI can prevent more outages & help accelerate outage recovery. Also, because AI is self-learning, grid predictions & control will improve with experience.
  - As AI learns a utility's grid, AI can suggest new strategies, efficiencies & opportunities for utility professionals to consider & implement

Microgrid & Artificial Intellience (AI)

- **Microgrids incorporates Distributed Energy Resources (DERs), EVs, & Demand Response (DR)**
  - **MGs can operate independent of the Main grid (in "islanding mode"), during extreme events.**
- **MG can decarbonize via incorporation of clean energy. Moreover, owners/ operators of over 2,000 MGs operating in the US, realize cost benefits from MGs' operation (College campuses, Malls, Hospitals IND end-users, & Military bases).**
  - **MGs are a promising community-level solution, consolidating distributed, decarbonizing technologies into local grids.**
- **To maximize resilience, decarbonization, & economic benefits of an autonomous MG system, optimization of real-time operation is needed. AI is well suited for these applications.**

- AI can provide active, real-time Synchronization & Control of MG resources, including PV, EVs, Stoarge & DER.
- MGs also provide an opportunity for beneficial energy arbitrage, which can increase the affordability of MGs, reduce net electricity costs, & benefit both the MG & the Main grid.
- Here again, AI is a crucial enabler:
  - AI systems can optimally model, control, & dispatch individual devices & Resources in such a way that can optimize energy sharing & trading between individual connected MGs, as well as between MGs & the main grid. This can improve the stability, reliability, resilience, affordability, & energy efficiency of the entire system
- AI can process vast amount of data, perform predictive grid modeling & dynamic grid control , & facilitate autonomous Grid Management. With AI, utilities, IPPs, & developers can efficiently route energy to where it is needed most, from any energy source.
  - AI applied to Grid Management holds the key to a cleaner, more reliable & efficient grid

Artificial Intelligence (AI): Solution for modern Grid Management?:

- AI enhances grid resilience to extreme weather and/or wildfires
- AI makes mass deployment of clean energy , possible, to reduce carbon emissions

AI delivers benefits Energy Management, including:

- Distributed Energy Resources (DER) /Distributed Energy Storage (DES) / Microgrids (MGs)/ Electric Vehicles (EVs)/ Demand Response (DR)

AI-controlled distributed RE Gen, DES, EVs, DR & MGs can provide:

  - Black sky benefits: enhanced extreme weather/ wildfire resilience
  - Blue sky benefits: Operational advantages & enhanced affordability
  - Future sky benefits: Decarbonisation that will benefit society in future

- Key areas where AI offers important benefits: Islanded microgrids, virtual power plants, building Smart sensors, & EVs

AI-CONTROLLED MGs FOR RESILIENCE

- AI system can accurately forecast about Temp spike coming at a particular time of day & then proactively use Battery Storage capacity on the grid, either on its own or it can suggest this to utility staff
  - Utility can be ready for such emergencies, without needing to start diesel- or gas-fired peaking stns.
- MGs may be created & operated by Discoms (to maintain power to remote communities or critical facilities during a storm or disaster) or by large customers to meet their Demd, with resilience & sustainability goals.
  - MG can enter "Island Mode" (operating independently of the Main Grid) to maintain local reliability & relieve grid stress, & then reconnect under favourable conditions.
- However, timing & managing these disconnections & reconnections is a delicate process; as discrepancies in voltage levels & other factors can increase the Grid problems.
- AI can monitor & manage all variables, so MG & Utility grid are both synched up smoothly & gradually to bring a MG off the Main grid, & bring it back on, that reduces stress on Grid, as well as on MG assets.

Grid Resilience: Islanded Microgrids

- Govt agencies can utilize AI to enhance Clean energy predictability & MG resilience during extreme weather or cyber attack events. This can help to ensure that islanded MGs continue to operate autonomously.
  - Moreover, AI-based MG control can address challenges, such as energy waste from curtailment or dumping of solar & wind power when Demd is low & can efficiently route this excess clean energy to charge storage resources, pre-cool buildings, etc.
- Multiple MGs can be synchronized & controlled, further enhancing autonomous operation, if one MG fails.

Virtual Power Plants (VPP): Solar & Storage:

- AI will do for energy what the internet did for personal computing: energy on Demd, sourced from anywhere, & always accessible.
- VPPs makes this vision, a reality. In a VPP application, energy sourced from decentralized resources (RT solar, Distributed Storage, & EV Battery Storage) can be aggregated across a community.
  - In this arrangement, the AI-based controller sends energy dispatch instructions to individual customers, or transfers excess battery energy back to the main grid.

Microgrids in India

- India currently has a 380 GW (+) installed Gen capacity, with 70% coming from coal. India has installed Solar microgrids providing around 2 MW electricity so far, but has ambitious plans.
- Large private investments are flowing in too, such as the partnership between Tata Power & Rockefeller Foundation to set up 10,000 MGs by 2026. This project is expected to support 100,000 rural enterprises, create 10,000 new green jobs & provide irrigation for over 400,000 local farmers.

Role of MGs in India's Clean enery:

- Microgrids have the potential to boost the economy by bringing electricity to remote regions & allowing small-medium businesses to grow.
  - For example, in remote Ladakh Himalayan regions, Solar MGs have boosted tourism income within about two years of being deployed.

- As indicated by Prof. Mahesh Bhave, based on some approximate numbers, for 85,000, 2MW MG, providing 170 GW at a cost of $430 billion (US$ 2.53 Bn/GW). For a cola plant It takes $1,25bn/MW in India.
  - THM Gen is therefore cheaper than MGs, but it is worth noting that cost of MGs is coming down quickly as more scale is reached.
  - Coal also enjoys substantial Govt subsidies & places an enormous burden on climate & local ENV, which is unaccounted for in its cost.
- To conclude, as India plans to bring power to more & more people, it is important that this expansion happens with RES. In a way that takes us towards a decentralized Smart Grid & promotes local businesses without impacting the ENV *So the question is not of why, but how, to make that happen, with more MGs in system*

(Ref: Article in RE World dated 9/01/2020 by Priya Aggarwal)

SPI facilitates World's largest portfolio of Mini-grids (21/11)

- **Smart Power India (SPI), a subsidiary of Rockefeller Foundation marked the operations of its 500th Mini-grid in Laxmanpur, UP, facilitating the world's largest portfolio of the mini-grids. Its total capacity now stands at 15.1 MW RE for the rural masses. Mini-grids are involved in Gen of small scale Energy for local use, where the Main Grid system has not reached.**
- **SPI is working in U.P., Bihar & Jharkhand for the last six years towards ensuring equitable energy access to the last mile to 500 villages. As of date, the program impacts half a billion rural lives. It has partnered with 13 developers including Tata Power Renewable Microgrid (TPRMG), Husk Power, Odisha Mining Corporation (OMC), Tara Urja, & MLINDA for the same.**

These are all mini-Grids not connected with Main grid & they run as indepenednt Grids

(Ref: News in Economic Times dated 21/11/2021)

Case studies of successful Microgrids

Case study 1: Horizon Power, Onslow, WA:

- Onslow is a remote coastal town located 1150 Km North of Perth, Western Australia & frequently affected by cloud events & coastal weather
  - With a population of 850, Onslow acts as an example of a remote MG within Horizon Power's service area & is representative of remote communities across the Globe. Onslow was using a mix of non-renewable energy sources, including an 8MW natural gas Gen, a 1MW Diesel generator, & a 1MWh Lead-Acid battery

Technology Used:

- MG controllers & Distributed Energy Resource Management Systems (DERMS)
  - 8MW Gas & 1MW Diesel power plant with 1MWh battery
  - 260 customer PV arrays (2.1 MW) & 500 KWh of customer-installed batteries
  - 1MW utility-owned Solar PV arrays with 2x 1MWh utility batteries

- Onslow has a small network size of 11MW serving a 4MW peak load. This combination of intermittent RE Gen & a Small network was causing grid instability, with the threat of black-outs & damage to electrical equipment.
- A multi-variable optimization (DERMS) algorithm takes into account local weather, cloud cover, Gen, storage, customer load & other variables & provides constant visbility & increases confidence levels in AI based forecasting. This allows the operator to make more accurate decisions to improve network reliability & & optimise the operation of distributed energy resources (DER) every 5 minutes
  - In similar situations in other towns, utility suppliers have limited the input of RES in order to protect the grid. However, Onslow Horizon Power, did not want to do this as it would impact WA's RE goals. Instead, it has set out to integrate multiple RES & batteries with existing infrastructure in a controlled MG.
- With this management, the grid is more reliable & it has tripled its RE hosting capacity, enabling reduced Carban emissions

Santa Rita (SR) , Jail, Micro Grid in California

SR Jail: opened in 1989 in Dublin, CA & houses over 4,000 inmates. Peak DEMD: 3 MW.

- **It has 1.5 MW of PV/ 1.0 MW molten carbonate fuel cell: 2 MW (4 MWH), Li-Ion battery**
- **Back-up DG can function grid connected or islanded using Li-Ion battery as balancing resource. Battery & a sophisticated switch allows SR Jail to island & reconnect at will.**
  - **PS is controlled by CERTS Microgrid Technology embedded in the battery.**
- **Over past decade Alameda County, which operates the Jail, has installed a Series of Distributed Energy Resources (DER), (Solar/ Wind/ Fuel Cell) to reduce consumption**
  - **SR Jail has also undergone a series of efficiency improvements to further reduce consumption.**

Western Power Kalbarri MG (Western Australia)

Key features

- Managing Demd fluctuations with RE & data, thro' harnessing local RT solar PV, along with wind & battery storage to create a MG system, & application of scenario planning to determine the best timings & configuration for on-going stability. During outages MG maintains supply to community using both solar/wind, & battery storage.

Location:

- Kalbarri (10,000-inhabitant coastal town) is located 570 Km North of Perth, Western Australia, affected by seasonal tourism which can increase the population by up to 10 times at certain periods. Kalbari town is also subject to a harsh climate, with salt, dust & rainfall interfering with the 140 Km HV feeder that runs from Geraldton City

Microgrid Type: Remote Residential & Commercial MG with BESS

Technology:

- Western Power's in-house tool, the Grid Transformation Engine is used to run scenario planning to determine timing & configuration of MGs to ensure grid stability & meet other goals.

Outcomes / Benefits

- MG that makes most of local energy, uses data & analytics to manage Demd, & has resilience by being able to run independently from the main Grid.

RE in place of Trans Augmentation

- In many places around the world, existing Trans feeder lines are aging & also are exposed to hazards such as **bushfires & storms: a growing problem as the world faces Climate Change.**
- **Cost of replacing Trans lines to ensure reliable energy availability is too high. MGs become cost-effective solution, while the CAPEX for MGs may be similar traditional grid infrastructure, the lifecycle cost of MG is lower**
  - MG can be even more cost effective if it doesn't need to be connected to a Main grid & **MGs also increase energy resilience, as MG can be 'islanded' if the Main grid fails.**

Horizon Power, Bushfire Restoration, Esperance, WA:

Location:

- Esperance is located on Southern coast of Western Australia. **It is a remote town which experienced bushfires that destroyed hundreds of wooden power poles in 2015. Considering extensive costs of replacement, along with a goal to build more energy resilience for the town, a MG was an effective solution**

Effective replacement for damaged T/Ls:

- Horizon Power built a Microgrid using a combination of Wind turbine (9MW), Solar PV (4MW) & Battery Storage.
- By avoiding long T/Ls, projected annual savings in O&M costs for the WA Govt are around $10 million. Esperance's power can now be 'islanded' to help it remain operating, in events such as a bushfire. **Project has the added benefit of delivering a 50% reduction in carbon emissions, as well as ability to expand the capacity of Wind, Solar & Battery in future.**
- By delivering energy independence to Esperance, which are at risk of **power outages due to damage to T/Ls**. It will also increase use of RE across WA, with project expected to reduce carbon emissions by ~128,950kg CO2-e per year

Technology

- Combined Wind turbine (9MW) & Solar PV (4MW) Gen with Battery Energy Storage meeting current & expected future power needs 24/7.
- Continued advances in wind turbine technologies significantly increasing Gen capacity

Outcomes / Benefits:

- Increased Energy resilience as failure-exposed long T/Ls are no longer required. If T/Ls are lost due to bad weather, the MGs can be islanded & the supply continues.
  - Avoiding long T/Ls also decreases CAPEX & O&M expenditure
- Over 50% reduction in carbon emissions.
  - Ability to expand capacity: planned expansion projects to increase Wind, Solar & Battery Capacity.
- Up to 46% of Esperance's TTL DEMD being supplied by RE

Energy Access:

- Regional & remote communities in places all over the World, share similar energy supply challenges. Servicing remote communities or IND operations with main power grids requires construction & maint of long & expensive T/Ls, which can be hard to upkeep & are often susceptible to damage from disruptive weather events.
  - Similar energy access challenges appear in refugee camps & disaster relief situations, where T/L infrastructure may not exist & hence have the challenge of relying on imported diesel for power Gen, which can make them vulnerable to oil price shocks

Case study: Tonga Island Villages (Schneider Electric)

Key features:

- Building autonomous MGs using Solar PV & Battery Storage, providing more reliability & access to energy at a reasonable cost

Location:

- 60 remote off-grid villages without main grid access in Tonga, an archipelago of 169 islands in South Pacific Ocean. 80-520 households per village

Microgrid Type: Remote MGs in Rural communities

Technology: Off-Grid solar PV & Battery Storage.

Outcomes / Benefits:

- Provides access to energy at a reasonable cost where main grid is not accessible Reduces dependency of rural communities in developing nations on diesel & reduces the high/fluctuating OPEX of diesel power Gen & vulnerability to oil price shocks.
  - Overcomes relatively massive capital outlay required. In developing regions where there is no Main grid, development of MGs can be inspired amongst the community by drawing parallels to mobile phone networks, which have overcome the obstacle of heavy infrastructure investment.
  - Access to electricity thro' 100% RE without dependency on Diesel The 60 sites have become autonomous power plants (from 15kW to 75kW)

Powerledger, UP Peer-to-Peer (P2P) Energy Exchange

- In UP, P2P trading solution was evolved to benefit consumers, prosumers & Discoms & was essential for a more interactive grid. Powerledger's solution was to incentivize the uptake of Distributed Energy Resources (DERs) in UP thro' a market-based mechanism instead of relying on a subsidy-based mechanism (net metering).
  - Powerledger provided valuable opportunities to UPPCL to learn how best to implement all aspects of blockchain enabled P2P electricity trading including defining network tariff to support the wider rollout of P2P electricity trading; & understand impacts of P2P trading on Dist network.
- These findings have enabled legislative change to allow P2P trading in UP. In achieving this, affordable electricity can be distributed to the un-electrified population of UP .

Technology:

- Powerledger Grid application (Residential MG)
- Smart Meter based on GPRS communication installed in 12 buildings, including 9 prosumers & 3 consumers. Billiing System integrated with the blockchain platform & Smart meters.

Key features

- Optimize electricity usage & provide prosumers more flexibility in price when carrying out trading of energy generated from Roof Top Solar,
- Assist customers who want to buy Green power by allowing them to purchase energy from RT Solar thro' peer-to-peer trading.
- Reduce Dist loss by encouraging local Gen & facilitate decongestion in Dist network.
- Blockchain allows transparency in transaction & negate the role of third party in transaction of energy. Blockchain also ensures traceability of energy, allowing utility to trace prosumer & consumers to help in proper accounting & billing.

Outcomes / Benefits:

- In P2P energy market buy price was 43% lower than the retail tariff. Thus will further incentiviz uptake of DERs.
- UPERC is the first ERC to issue a tariff order which provides a directive to all utilities in UP to implement P2P Energy trading, which allows greater opportunity for affordable energy to reach un-electrified rural areas. Thus improving economic welfare of the State
  - Next step being developed involves bringing P2P energy trading into a local energy market to drive grid efficiencies

AGNEW GoldMine Fields & EDL Energy, Northern Goldfields, WA: Decarbonising the Industry

- MGs offer potential for organisations to generate more RE locally, while having less reliance on Grid T/Ls & reducing exposure to fluctuations in fuel costs.
  - Agnew Mine is located in Northern Goldfield Regions in remote West Australia requiring constant, reliable power to support its Gold Mining activities, but is prone to power outages due to difficulties in maintaining Trans lines
- It had a goal of using more RES, while also minimising power outages, due to reliance on extensive Grid T/Ls to reach a Central grid.
  - 54MW hybrid digitally-managed MG with 16 MW Gas/ 3 MW Diesel, 18 MW Wind, 4 MW Solar & 13MW/4MWh Battery Storage System.
- MG is managed digitally, focusing on predictive Solar & Wind forecasting, combined with dynamic Load Shedding & Demand management to reduce, the need for spinning reserve.
  - Around 55-60% of Agnew Mine's energy is now RE, which can go up to 80% in the right weather conditions. The site is more independent, with reduced reliance on Main grid power.

Agnew gold mine, located near Leinster, WA

Outcomes / Benefits

- Developed the business model for remote IND operations to deploy a MG utilising an IPP, resulting in reduction of Tech & Comm risk.
- Overcame logistical issues such as transportation of large turbine blades which required upgrades to ports.
- First mine to demonstrate the effectiveness of Wind power in a mining environment.
- 55-60% of Agnew Mine's energy is now sourced from RE ,up to 80%, if weather conditions are good.

Cities of the Future

- Metropolitan areas around the world are seeking more energy reliability to be ready for extreme weather events
  - such as Winter Storm URI which had a dramatic impact on Texas Energy supply in early 2021.
- Planners also want to use more REs to reduce carbon emissions to help reduce GHG impacts. MGs have potential to help urban areas to achieve these goals.
  - MGs could be used in large communities such as a suburb or business park, shopping centres, commercial buildings or schools/Hospitals .
- There is potential to have a series of interconnected MGs, so that if one MG becomes unstable, it can be isolated, so that it does not affect the remainder of Main grid.
- Likewise, connected MGs can support one another by providing power, energy storage, or other services should a problem arise with one particular MG
  - Key benefit is the ability to use more locally generated RES such as solar PV. Urban MGs could facilitate more DER in the market, & greater customer choice.

Schneider Electric's Oncor campus MG, Texas: Flexible operations & RE

- Oncor System Facility in Lancaster, Texas (USA) (a 100 Acre facility) , was experiencing power outages due to either local or main grid issues.
  - It had 9 existing energy sources including 2 solar PV arrays, a propane micro-turbine, 5 Gens & Batteries.
- To build in more resilience & stability, a MG was commissioned by using existing infrastructure, operating all 9 existing Gen sources, to optimise use of DERs with a DERMS.
- Schneider Electric divided the system into four connected MGs which can all connect or disconnect to Main grid, as required.
  - DERMS carries out real time monitoring & communication about load, Gen & storage. With automated optimisation software, the DERs are balanced to maximise use of REs to meet sustainability goals, while helping to reduce the total cost of providing energy.
- As a result, critical loads are protected by automatically switching from traditional grid to MG sources. The system has flexibility, fault tolerance, & makes better use of RES .

Technology:

- 9 existing energy sources: 2 PV arrays, 1 Propane micro-turbine, 4 Gens & 2 batteries, connected to Main grid.
  - System divided into 4 connected MGs.
- Ability to smoothly connect/disconnect to Main grid introduced.
- A monitoring & communications system that provides info about load, Gen & Storage including communicating info with the Main grid.
- An automated optimisation software balances DERs to reduce TTL cost of providing energy while maximising use of Res.
  - When traditional grid supply fails, system automatically compensates by increasing local PV Gen, supplemented by Battery Storage

Outcomes / Benefits:

- Reliability: Critical loads protected by automatically switching seamlessly from traditional Main grid to MG sources.
  - Flexibility: Multiple MGs & energy sources working harmoniously to meet energy Demands
- Integration with traditional infrastructure: Communication with traditional Main grid using standardised communication protocols

(ONCOR Texas Campus is now ready to face any emergency due bad weather, which was not so, in Jan 2021, beacsue of 4 strong MGs)

T77- BCPG, Thailand, Powerledger: Peer-to-Peer (P2P) Energy Exchange

- With a National aim to increase RE Gen to 30% by 2036. Powerledger's uGrid technology was trialled by Thai RE business BCPG & Thai Utility Metropolitan Electricity Authority (MEA) to trade RT solar power between an International school, Apartment complex, Shopping centre & Dental Hospital in Bangkok to increase to increase investments in Solar projects & use of Solar energy
  - Powerledger's Blockchain technology provided the "transactive layer" to enable P2P trading, monitoring of energy transactions between participants, which generates invoicing to allow for settlement, & summarises trading position of individual participants.
- This maximised the RE utilization, within the precinct, as RE is cheaper than grid energy, providing greater income for solar asset owners BCPG, while reducing electricity costs for participants

Project Location : T77, Bangkok, Thailand:

- **RE produced by each entity is used within their respective buildings,so that residents & tenants can have lower energy cost**
  - **Trading could then occur, as each building has different load profiles.**
  - **Excess energy is sold to other buildings thro' P2P Energy Trading system.**
  - **If there is an energy surplus from all buildings, it is sold to Energy Storage System. (ESS)**
  - **If ESS is full, surplus energy can be sold to the Main grid.**
- **All entities can act as buyers or sellers of RE, in real time, thro' the blockchain enabled software.**

Technology:

- **Powerledger uGrid & xGrid applications: 109 Smart meters**
- **RT solar systems with a capacity of 635 KW & co-located battery storage system (BSS)**

T77, Thailand, Solar array

Outcomes / Benefits:

- **18% of energy consumed within the precinct (part/ward of City) came from RES**
- **Technology maximized RE consumption within the precinct (Part of city) , which was cheaper than the Main grid Power.**
- **It provided greater income for the solar asset owners, while reducing electricity costs for participants & allowing for P2P trading in real-time.**
- **Project led to expansion of this innovative Trading scheme & saw to additional residential complexes & a Smart office building being added to the project. Bringing the No. of multi-tenanted buildings to 7 in total, with a total of 1.1 MW of Solar PV connected**

California to Consider 4 Utility Microgrids to Help Avert Possible Capacity Shortfall (02/11)

- A plan by San Diego Gas & Electric (SDG&E) to build 4 utility microgrids won an initial nod last week in a proceeding underway before the California Public Utilities Commission (CPUC) to avert a possible capacity shortfall for the next two summers.
  - Utility MGs were included in a "proposed decision," by CPUC. Final decision on MGs will come during the CPUC's Dec. 2 meeting
- In addition to MGs, CPUC will look at a range of other energy projects & ideas to address the potential shortfall (R.19-09-009).
- Gov. Gavin Newsom issued a warning about the shortfall in California State in July 2021, & soon after, CPSU began soliciting ideas on how to address it.

Details on the SDG&E microgrids:

- SDG&E intends to build two MG projects at its Boulevard & Paradise S/s. Utility is still working out specifics on two others.
- Boulevard & Paradise MGs would serve low-income communities that have already installed REs. Utility would add long duration storage, & MGs would provide power for public safety operations, such as fire & police.

Solar MG Proposed for "Southern California Army Airfield"

- **Joint Forces Training Base Los-Alamitos Army Airfield in Orange County, California (located about 20 miles southeast of Los Angeles & 5 miles from Pacific Ocean), is planning on erecting a 30-MW Solar MG. California Army National Guard, which operates the airfield, would develop the Microgrid.**
  - **Joint Force Training Base Los-Alamotos is home to a variety of California National Guard & US Army Reserve units & hosts many other military & civilian organizations**
- **MG would provide increased energy resilience & security. Airfield's mission is to provide critical response during emergencies in Southern California region. A 2020 Army directive requires all of its units to ensure reliable & high-quality power & water to continuously sustain critical missions & a Department of Defence Directive requires its facilities to produce or procure at least 25% energy they use, from RE resources by 2025 & beyond.**
  - **California Army National Guard, with technical support from Army's Office of Energy Initiatives, evaluated the potential ENV, socioeconomic & cultural effects of solar PV system, which includes Energy Storage & backup Diesel Gen. California Army National Guard has selected a developer to install & operate the MG.**
  - **Developer would also run both UG & OH interconnection lines to serve Southern California Edison's (SCE) regional grid connection points & the airfield's electrical infrastructure.**

- **Single-Axis-Tilting Solar PV Arrays would be built at two separate 15-MW sites on the airfield, & power generated would be fed directly into SCE's Grid.**
  - **Single-axis-tilting solar arrays were selected to prevent glint & glare for operating aircraft & nearby residents**
- **Battery Energy Storage System (BESS), to be co-located on sites, would store power & release it to Regional Grid, when power is not being produced by solar arrays, for example, when Sun is not shining. Diesel Gen would be located at a separate nearby site. MG would operate independently if grid goes down because of natural disaster or terrorism.**
  - **If either of those events happen, one solar array & one BESS would provide the nominal 3-MW emergency power requirement to the airfield. If they were unable to provide that power, diesel-fired Gen would meet the 3-MW requirement**
- **Current plan is for other Solar array & BESS to not be connected to MG & instead provide power only to Regional Grid. However, at some point in future, Solar PV array & BESS could be connected to second system to also provide energy to the installation during a grid outage.**

"US House passed Microgrid Tax Credit in Vote" (19/11)

- Microgrid tax credit cleared the US House of Representatives in a Friday morning vote (19th Nov 2021) approving President Joe Biden's Build Back Better Act (H.R. 5376).
- The 30% tax credit would apply to MG controllers for projects that begin construction before Jan. 1, 2027. It is part of a roughly $2 trillion plan that provides an array of boosters for clean energy, along with spending on social programs.
  - MGs, energy storage, biogas, linear generators & dynamic glass (a form of glass used to heat & cool structures) are included among the new technologies, the bill makes all these eligible for a 30% investment tax credit.
- The Bill now goes to the Senate where its fate will be decided.
- MG Tax Credit emerged from the MICROGRID Act, which was introduced by California Congressman Jimmy Panetta, D-Carmel Valley. As a member of the House, Ways & Means Committee, Panetta secured the Act's Microgrid tax provisions in the Build Back Better plan. Tax credit will help municipalities & essential INDs to build & deploy MGs & leverage private capital to help build a more resilient Grid

- California, has been particularly hard hit by power outages. Grid failures related to wildfires & grid issues driven by extreme weather events. Expanding & deploying MGs will provide a cleaner, more reliable way to keep critical infrastructure powered, when the Main grid fails, protecting families & keeping the businesses running.
- Build Back Better Act extends Solar Tax credit, which would cut cost of RT solar by up to 30%. Bill provides a tax credit for EVs that would cut as much as, $12,500 off per EV purchase.
  - Other clean energy provisions provide rebates for home energy efficiency & electrification projects, create a program to reduce methane emissions & electrify US Post Office vehicles.
- Credits, such as those for Solar, Storage & EVs, also provide advantages for MGs because they are common elements of a MGs. If the bill becomes the Law, it will represent the largest investment in Climate Change ever made by the US Govt.

- For MGs, bill would add to support the technology received in the $1 trillion infrastructure bill H.R. 3684, signed into Law by President Biden on Nov. 15. Known as the Bipartisan Infrastructure Deal, the bill names MGs as eligible for funding within programs to improve Trans, electrify transportation & improve rural & remote areas of the US.
  - MGs are also singled out for funding in resilience programs to help States to adapt climate disruption & for connection to Trans, transportation or telecom infrastructure corridors in Alaska, Hawaii or a territory of the US.
- Several energy advocacy groups praised House passage of Build Back Better. Bill is "the closest the US has ever come to taking action on climate change at the scale needed to create a better future.

- "It's a moment to approve legislation that would rapidly decarbonize the US Power System, increase resilience of frontline communities to extreme weather, & spread jobs/prosperity thro' an IND renaissance" says Jimmy Panetta.
  - Plan moves the US to establish a stable, predictable & long-term clean energy tax platform that will spur critically important investment in RE, ESS & advanced grid technologies

Realities of Running & O&M of a Microgrid

- **MGs are designed to act automatically & independently basically by utilizing strength of AI, but this doesn't eliminate the need for O&M for MG**
  - **It's Important to define in advance how the MG will be maintained &, if needed, designating appropriate Authorities for particular tasks. Especially when issues arise, one doesn't want to waste time determining, who should & can fix a problem.**
  - **There is a need of "Real-Time Monitoring", which allows you to see how your system is operating at any moment. If you have visibility to the first fault, you could correct the problem & any subsequent faults which would have taken down the system, would be avoided**

MG Maintenance:Common Pitfalls & Mistakes:

- **Not monitoring the system/ Not designating who's responsible for O&M/ Ignoring minor hiccup/ Not customizing maintenance schedules/ Neglecting backup inventory/ Forgetting to train new staff.**

Role of Microgrids in India

- Electricity has been a prime-mover for overall development of India
- Microgrids are small & localized versions of a power grid for areas which area without Central Electricity Grid or poor Central Grid connection.
- Long before the concept caught up with the World, people in India were using MGs & Minigrids with Diesel Generators. In the absence of electricity, they were powering small commercial facilities, farms & villages.
- But now, the focus has moved towards making the Microgrids RE-powered & expanding their reach.
  - As an example, a village in Jharkhand, many people are purchasing electricity thro' a Solar-Battery powered MG, despite having a grid connection at home; due to frequent power cuts that can last for days & disrupt small businesses like a local store or a poultry farm.
- MGs are not as popular in bigger towns & cities in India, compared with that in more distant & smaller locations, despite irregular power connections.
- Mnay cities are well-connected to the Central Grid, so perhaps residents have hopes of getting uninterrupted power & do not see much benefit in investing in an alternate system of MGs. However, to deal with blackouts, it is common to use diesel Gens, which are very costly (One liter of disel generates 2.5-3 Units: over Rs 33PU: feul cost)

- Gen costs in a MG depends on location, capacity, installation costs, etc. & so it is difficult to generalize the PU tariff for a MG.
- Although MGs have their benefits, their electricity is not very cheap, combining with Storage to counter the intermittency as well as cost of controls of RES, often MGs are costlier than grid electricity.
  - For example, in a 2016 study at Stanford, it was concluded that AVG price of grid electricity in village in Guj is $0.06/kWh; however, the integration of a solar-battery MG would cost the village up to $0.38/kWh. Nevertheless, REs would still be a good replacement against diesel-only power Gen that can cost up to $0.57/kWh.
- Some believe that the benefits of MGs outweigh the additional cost. Availability of electricity eventually enables local shopkeepers to stay open for longer, as they no longer depend on the daylight.
- In a Nation with AG as the dominant source of livelihood, electricity from MGs has also promoted a shift to solar pumps.
- Despite all benefits, setting up a formal MG network in India is not without its own challenges. There are many Regulatory & Bureaucratic hurdles to cross, as well as the challenge of educating people who are receiving electricity for the first time, & encouraging them to adopt a non-wasteful behavior.

- From a business perspective, there are many challenges around MG scalability, power theft & an eventual extension of Central Grid. In many cases, MGs also face high O&M costs due to little availability of local technicians to look after the systems.

WAY FORWARD:

- A International Microgrid Association (IMA) study found that in short term, people expect that there will be relatively low adoption of MGs, as a specialist field, & their use will be constrained to remote areas.
  - However, with in 5-10 years, the study indicates that MGs would be more widespread, extended to C/I & academic Institutes , as well as samll neighbourhoods, towns, housing developments & estates.
- It is also anticipated that in future, MG will be in the portfolios of major energy vendors, moving towards greater integration of MGs with main Grids, as part of a Smart Grid system.

In Next 5 years (upto 2026)

- Relatively low adaptation of MGs
- Adoption either in fringe of the Grid, already decentralised island scenarios, remote areas or in pilot/ demonstration scenarios
- Concept will be starting to gain acceptance, as a specialist industry

Within 10 years (upto 2031):

- Expanded use which extends to C/I, Academic Institutions , Hospital , IND areas, towns, housing developments & estates
- Increased customer participation in the market. MGs will be in the portfolios of major energy vendors in the market

Within 15 years (upto 2036):

- Developed into a common concept, MG will be trusted & reliable option
- Coherent business models, Cos. specialise in design & installation
- Integration of MGs (as aggregated Virtual Power Plants) with the Main Grid as part of an intelligent Energy System

Time to encourage Microgrid is "NOW"

- Microgrids are a proven technology, with a number of highly valuable applications suited to developing & developed landscapes, Regional & Metropolitan, Residential & Commercial Complexes. MG should be widespread in the next five years.
  - Barriers prohibiting a faster MG Adoption: Regulations & strict control & safety compliances
- With the push for decarbonisation & MGs proven ability to improve sustainability, efficient energy management & energy resilience, now is the time for businesses & Govt for ACTION, across the world, to encourage the adoption of MGs.
  - It makes sense for every new development to consider implementing MG technology to enhance energy system & create better outcomes for customers, Discoms & commercial interests.
- With adoption of Artificial Intelligence (AI), MGs are critical to success of future of Energy as AI will add to resiliency & controllability, sustainability with the Main Grid

- Not only are Discoms moving towards electrification for resilience purposes, but they're also seeking out energy that's located close to where it's used. The call to action for sustainability creates opportunities for MGs.
  - It's our duty as proactive planners, we need to educate all stakeholders about the role MGs, can play in meeting Discom's goal of resilience & sustainability.
- Limitations of RE, when it is used without other forms of energy are well known (because of its intermittency), MGs typically employ multiple energy resources & bring ability of a smaller part of GRID to island from Main Grid during a power outage, which allows them to provide electricity to their hosts (essential loads: Airports, Railway stns, Hospitals & Malls)
  - Solar is great for decarbonization & can be cost-effective even with battery storage, but can't provide resiliency. In the past, MGs were made up of customized systems. But presently more & more, MGs are becoming standardized.

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Thanks! Your kind response is awaited!!

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